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TRSB MICROWAVE LANDING SYSTEM DEMONSTRATION PROGRAM AT JORGE NE--ETC(U)
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TRSB MICROWAVE LANDING SYSTEM DEMONSTRATION PROGRAM AT JORGE NEWBERY AEROPARQUE BUENOS AIRES, ARGENTINA.

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OCTOBER - NOVEMBER 1977

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U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research & Development Service
Washington, D.C. 20590

240 550

NOTICE

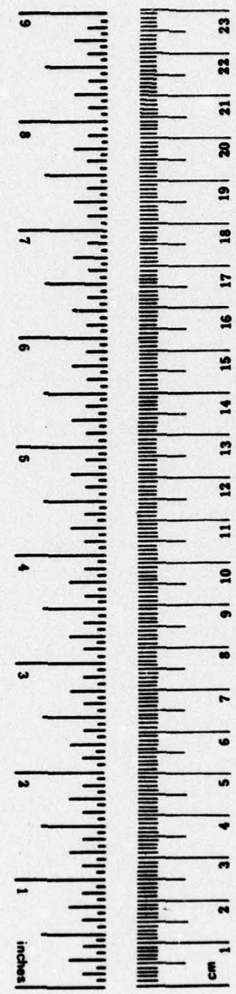
The United States Government does not endorse products or manufacturers. Trade or manufacturer's names appear herein solely because they are considered essential to the object of this report.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

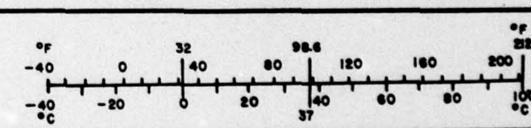
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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16. Abstract

The FAA is conducting operational demonstrations of several TRSB hardware configurations at selected airports in the United States and abroad. The first demonstration was at Cape May, NJ, using the Small Community System.

The second demonstration was at Jorge Newbery Aeroparque in Buenos Aires, Argentina, using the Basic Narrow TRSB collocated with UHF/VHF ILS. This system was designed for azimuth proportional guidance ±40 degrees about the runway centerline, elevation proportional guidance from 1 degree to 15 degrees, and coverage of at least 20 nautical miles in heavy rain. Most of the flights were in the NASA B-737 terminal configured vehicle which recorded TRSB angle data, together with ground tracking data from radio theodolite and optical television tracking equipment. Flight profiles included completely coupled, descending, curved paths to a close-in intercept (2.0 and 1.1 nautical miles) of runway centerline, followed by autoland and roll-out on runway. Results using the Basic Narrow System are:

1. Can be collocated without adversely affecting ILS performance,
2. The TRSB system required minimal site preparation and installation time,
3. Signal guidance quality appeared to be excellent,
4. Guidance signal quality within ICAO requirements for a "full capability system" and requirements for FAA proposed "TRSB Autoland,"
5. The system demonstrated near total immunity to interference from propeller modulation, and
6. With precision DME, the system can be used for noise abatement procedures, including segmented elevation angles and curved approaches.

17. Key Words
Argentina
TRSB
MLS
Basic Narrow System

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INTRODUCTION

During the past several years, extensive engineering evaluation and flight testing has been accomplished on Time Reference Scanning Beam (TRSB) Microwave Landing System (MLS) equipments at the Federal Aviation Administration's (FAA) National Aviation Facilities Experimental Center (NAFEC), Atlantic City, New Jersey, and at the Auxiliary Naval Landing Field, Crows Landing, California. TRSB MLS is the United States and Australian candidate submission to ICAO as the future all-weather landing system which would replace ILS.

In March 1977, the ICAO All Weather Operations Panel (AWOP) recommended TRSB to the Air Navigation Commission (ANC) as the preferred candidate system for international adoption. This decision by AWOP followed a 15-month period of intensive and comprehensive assessment of all competing microwave landing systems conducted by a working group of international experts under the sponsorship of the AWOP. The ANC forwarded the AWOP recommendations to the ICAO Council, whereupon the Council has scheduled a worldwide meeting for April 1978, to address the question of selecting the new international standard for an approach and landing system to replace ILS. Meanwhile, the Council has encouraged proposing States to conduct demonstration and flight trials at operational airports. Accordingly, the FAA has developed a program to conduct operational demonstrations of several TRSB hardware configurations at selected airports in the United States and abroad. These demonstrations are intended to show that TRSB is a mature system that meets the full range of requirements from general aviation use to scheduled air carrier operations, for Category I to Category III autoland, under good or poor airport siting conditions, and under extreme weather conditions. Additionally, these demonstrations provide opportunities for representatives and officials of the international aviation community to gain first hand knowledge of TRSB MLS, and assess its applicability to their particular requirements.

The first operational demonstration of TRSB away from NAFEC was conducted at a small community airport in Cape May, New Jersey. At the invitation of the Organization of American States (OAS) and the Argentina Government, the second demonstration was conducted at Jorge Newbery Aeroparque in Buenos Aires during a meeting of the OAS Aeronautical Telecommunications Group.

Aeroparque is a joint use municipal airport, in the midst of a densely populated area, with a large number of scheduled commuter flights.

Runway 13/31 is the sole runway. It is 2100 meters (6900 feet) long and 40 meters (131 feet) wide (Figure 1). Normal low visibility approaches are to Runway 13 which is served by a UHF/VHF Instrument Landing System (ILS).

DISCUSSION

Two TRSB MLS equipments were displayed at Aeroparque. The Small Community System manufactured by Bendix, which had been demonstrated at Cape May, New Jersey, was installed on temporary platforms at the Military Aviation Museum for static display (Figure 2), and the Basic Narrow TRSB also manufactured by Bendix, was collocated with the ILS on Runway 13 for demonstration flights using U.S. and Argentine aircraft. A tactical man-portable azimuth TRSB subsystem, manufactured by Texas Instruments, was also on static display in the Aero Lineas Argentina Crew Lounge which was used for presentations and preflight briefings.

The Basic Narrow TRSB was designed to provide azimuth proportional guidance over an area of plus and minus 40 degrees about runway center-line. The elevation proportional guidance extends from 1.0 degrees to 15.0 degrees. System coverage distance is at least 20 nautical miles under heavy rain conditions, and much greater under less stringent environ-mental conditions. Performance specifications are presented in Table I. General information on TRSB is presented in the Appendix.

Equipment Installation

All of the ground systems and instrumentation equipments were transported by air to Ezieza Airport on 10/17/77, and transhipped to Aeroparque by two flatbed trucks that afternoon and on 10/18/77. Each of the trucks made two trips. One meter thick pads with mounting bolts had been poured for the elevation antenna and its associated monitor antenna by local workmen under the direction of Fuerza Aerea Argentina. Forms for similar pads for the azimuth antenna and its monitor were complete, but concrete had not been poured. The NAFEC installation crew proceeded to install the Basic Narrow Elevation equipment and the Small Community System while the azimuth foundation was poured and allowed to harden. The azimuth antennas were placed on the pads on the morning of 10/20/77, and the system was operational that afternoon.

Collocation with the field ILS was effected as follows: The MLS azimuth antenna was installed 145 meters (476 feet) from the stop end of Runway 13 on the extended runway centerline. It was 23 meters (75 feet) in front of the field localizer and 30.5 meters (100 feet) behind the azimuth monitor antenna.

The azimuth shelter which supported the identification antenna, side lobe suppression antennas, and Distance Measuring Equipment (DME) antenna was set on aluminum plates placed 75 meters (246 feet) off of the extended runway centerline on the south side of the runway. 76 meters (249 feet) of eliptical wave guide connected the shelter and antenna.

The elevation antenna and its associated shelter were 292 meters (958 feet) back from the threshold of the runway. The antenna itself and the elevation monitor antenna were 129 meters (423 feet) from the centerline of the runway on the south side, outboard of the field ILS glide slope antenna (Figure 3). The shelter was placed behind the antenna and connected with coaxial cable. Siting of the TRSB system is shown in Figure 4.

Portable power was provided by two 12.5kva, 60 hertz, 220 volt, single phase diesel generators. A third portable generator powered a demonstration van that displayed the computed position of the B-737 demonstration aircraft as it performed curved descending approaches on the MLS guidance. The demonstration van is shown in Figure 5.

Flight inspection of both the localizer and glide slope installation, prior to and after the TRSB installation, showed that the ILS performance was not degraded by the TRSB structures.

Airborne Installations

Three aircraft were used for demonstration of the Basic Narrow TRSB. One angle receiver and one DME interrogator were installed in a Fuerza Aerea Argentina Guarani, twin turbo prop, flight inspection aircraft. The equipments and their control heads were mounted on a removeable pallet for temporary installation. Coaxial cable connected the angle receiver to a horn antenna mounted in the cockpit behind the windscreen. An existing L-band antenna was utilized for the DME. The analog output of the angle receiver was connected to the Guarani flight inspection console for recording and to cross pointers in the cockpit. A digital DME indicator was placed in a display panel in the cockpit where it was viewed by observers.

A United States Air Force T39, twin engine jet aircraft with a digital autopilot and conventional electromechanical displays, was also used in the demonstration (Figure 6). This aircraft had been used before to demonstrate earlier TRSB systems, and C-band DME, but was equipped with a single TRSB receiver and L-band DME less than 2 months prior to the demonstration in Argentina.

Most of the demonstration work was performed by the NASA Boeing 737 Terminal Configured vehicle (Figure 7). This aircraft with advanced multimode displays and a digital autopilot, was equipped to record tracking data from a radio theodolite and from an optical television tracking equipment. The tracking data was compared to both elevation and azimuth outputs of the TRSB receiver and the errors recorded on paper tape along with the raw tracking and TRSB signals.

Demonstration

Two hundred and fifty observers from 19 countries attended the TRSB demonstrations between October 31, and November 4, 1977. More than half of the observers flew on one of the three demonstration aircraft. Summary statistics are presented in Table II.

The schedule of events shown in Table III was generally followed, but several additional tours and flights were performed to accomodate the large number of observers who wanted to see the ground equipment and fly onboard the aircraft. Each group was briefed on the status of the TRSB program, viewed the spanish language TRSB film, and was shown the flight paths to be flown by the B-737 and T39 demonstration aircraft. The groups were then transported to the demonstration aircraft and taken around the airfield on busses to examine the ground equipment and view the approaches from the ground and observe the aircraft tracks on the real time displays.

The tour groups met the aircraft after the final landing and boarded the aircraft for the next flight while the group from the previous flight toured the field. Interpreters on-board the aircraft and with the ground tour, translated the equipment descriptions and assisted on answering questions from the observers.

Several levels of sophistication in both ground and air systems were demonstrated or displayed. Light aircraft operators were interested in flying on the Guarani with conventional ILS displays and manual control, but most observers expressed an interest in the curved descending noise abatement approaches over the Rio de la Plata. These approaches avoided a densely populated area beneath the standard ILS approach path.

The NASA B-737 demonstrated completely coupled, descending, curved paths to a close-in intercept (2.0 and 1.1nm) of runway centerline extended followed by autoland and rollout on the runway. The terminal portion of one such approach with TRSB guidance and precision DME is shown in Figure 8. The USAF T39 demonstrated segmented glide paths and compound, curved paths again using only TRSB guidance and precision DME.

Passengers on the B-737 were rotated through several seats so that they might observe the flight path from the front cockpit, view the advanced displays in the experimental cockpit from which the aircraft is controlled, and see the instrumentation equipment in the cabin as the NASA engineers recorded the flight.

The B-737 demonstration approaches consisted of 90 degree intercepts from the river with a final straight-in approach leg of 2nm, and 60 degree intercepts with a final approach leg of 1.1nm. Almost 50 autocoupled approaches were made, of which 3 did not end in automatic landings. These two resulted from interception problems not related to TRSB. On one morning with winds of 40 to 50 knots and an apparent severe wind shear about 0.5 mile from threshold, the B-737 aircraft made autolandings. At least one T-tailed twin jet executed a missed approach during the same time period.

Performance Assessment

Ground based tracking for the TRSB demonstrations was provided by two different types of optical trackers. The azimuth tracker was a manually operated radio telemetering theodolite (RTT), which was used to transmit azimuth angle position to the aircraft via a transmitter operating on an unused UHF glideslope channel (329.0MHz). Physically, the theodolite was located on the extended runway centerline approximately 39 meters (128 feet) forward of the TRSB azimuth monitor antenna. The elevation tracker was an optical television tracker manufactured by British Aircraft Corporation of Australia, designed to automatically track a light source on the aircraft, and telemeter angular position back to the aircraft on a frequency of 126.25MHz. This tracker was located 15.6 meters (51 feet) toward the runway from the TRSB elevation antenna, and 7.8 meters (26 feet) closer to threshold. Its height was adjusted to make a 3-degree angle coincide with the 3-degree elevation beam at threshold.

The B-737 aircraft was instrumented for ground tracking. The analog outputs of the two tracker angle receivers were converted to digital data and compared with the digital TRSB angle data in an airborne central processing computer. The differences, as well as the two original angles, were then converted to analog form for recording on a light galvanometer strip chart recorder. Flight data was recorded during the B-737 demonstration flights. The final portion of these flights exhibited very short straight-in sectors varying from approximately 1.1 to 2 nm. The plan view of one such curved approach plotted during the flight, and displayed in the demonstration van, is shown in Figure 9.

A typical B-737 data plot is presented in Figures 10A and 10B. Figure 10A presents the elevation and azimuth error plots from threshold to approximately 0.9nm. The continuation of this run to about 1.84nm is shown in Figure 10B. ICAO error limit boundaries for reduced capability as well as full capability systems have been added to the plots as shown. A view of the plots presented in Figure 10A and 10B indicates that for elevation guidance, there is 0.1 degree signal variation. Although this variation is within the total ICAO (AWOP) "full capability system" specification, the reason for this variation is believed to be due to blockage by the commissioned glide slope monitor antenna. This monitor antenna is about 0.92m x 0.92m (3 feet x 3 feet), at an elevation angle slightly less than 2.0 degrees. This monitor antenna was located 9.23m (30 feet) toward the runway and 83.4m (274 feet) forward of the TRSB elevation antenna. The variation as shown, however, is within the elevation error allowed in the FAA proposed "TRSB Autoland Requirements."

Referring again to Figures 10A and 10B, the azimuth excursions are all within ± 0.05 degrees. By referring to strip chart recording from which Figures 10A and 10B were prepared (Figure 11), it is apparent that the noise evident in these figures can be attributed to the tracker, and is not due to TRSB. Including this noise, the total azimuth error excursions are all well within the ICAO bounds for full capability and reduced capability systems. This error is also well within the 4.15m (13.5 feet) linear error limit at threshold recommended in the FAA proposed "TRSB Autoland Requirements."

The Argentina flight inspection aircraft is the Guarani, a small twin engine turbo-prop aircraft. A TRSB installation was made in this aircraft, including an angle receiver and precision "L"-band DME interrogator. The TRSB antenna was temporarily installed to look through the cockpit wind screen. During the demonstration flights, the ILS and TRSB analog signals were recorded simultaneously on the aircraft on a two-channel ink pen strip chart recorder. No ground tracking was used during these flights.

By referring to Figures 12 and 13, examples are presented of TRSB and ILS comparative data taken on the Guarani strip chart recorder. Figure 12 dramatically demonstrates TRSB azimuth immunity to propeller modulation compared with the commissioned localizer at Jorge Newbery Aeroparque. At a power setting of 92 percent RPM, the interference ratio is approximately 5 to 1, at a power setting of 100 percent RPM, the interference ratio is approximately 16 to 1. Figure 13 indicates no propeller modulation evident on the TRSB elevation signal, while that appearing on the commissioned ILS glide slope averages about 50 microamperes peak-to-peak.

Additional data will be published as a working paper to ICAO.

SUMMARY OF RESULTS

The TRSB system discussed in this document is an economical configuration of TRSB hardware similar to the "Small Community System," but with greater volumetric proportional guidance coverages. Within the FAA, this configuration is referred to as the "Basic Narrow System." In addition to its economical system architecture, the information presented herein shows:

1. Can be collocated without adversely effecting ILS performance.

2. Signal guidance quality appeared to be excellent.

3. The TRSB system required minimal site preparation and installation time.

4. Guidance signal quality was well within ICAO requirements for a "full capability system" and the signal requirements for FAA proposed "TRSB Autoland."

5. The TRSB system was demonstrated to possess near total immunity to interference from propeller modulation.

6. The TRSB system with a precision DME can be successfully used for noise abatement procedures, including segmented elevation angles and curved approaches.

TABLE I
TRSB ACCURACY, PHASE III SYSTEMS

			BIAS (DEG.)	PATH FOLLOWING NOISE (DEG.)	PATH FOLLOWING ERROR (DEG.)	CONTROL MOTION NOISE (DEG.)	REMARKS
Basic Narrow	AZ	SPEC	.19	.08	.2	.07	at 50' on 2.5° G/S
	EL	SPEC	.08	.09	.12	.05	
Small Community	AZ	SPEC	.29	.15	.33	.10	at 150' on 2.5° G/S
	EL	SPEC	.11	.12	.16	.10	

NOTES ON TRSB ALLOWABLE PFE DEGRADATIONS (PHASE III CONTRACTS)

	PFE Degradation W/Distance	W/Azimuth Angle	W/Elevation Angle
Basic Narrow			
Azimuth	None	Linearly to twice C/L error at $\pm 60°$	None to 9°. Linearly to 2 times from 9° to 20°
Elevation	Linearly to 1.5 times at 20 NM	None	Linearly to 3 times from 2.5° to 20°
Small Community			
Azimuth	Linearly to 0.4° at 20 NM	Linearly to twice C/L error at $\pm 60°$	None to 9°. Linearly to 2 times from 9° to 15°
Elevation	Linearly to 1.5 times at 20 NM	None	Linearly to 3 times from 2.5° to 15°

TABLE II

SUMMARY STATISTICS

TRSB/MLS DEMONSTRATION - BUENOS AIRES, ARGENTINA, OCTOBER 31 THROUGH NOVEMBER 4, 1977

REGISTERED VISITORS	
October 31	64
November 1 (Press)	34
(Other)	16
November 2	50
November 3	46
November 4	40
Total	250 - plus many who wandered into the presentation and exhibit room

FLIGHT DEMONSTRATIONS	B-737	T-39	Guarani
October 31 (Observers)	20		
November 1	28	7	
November 2	19	8	?
November 3	31	4	?
November 4	20	8	?
Total Observers	118	27	24 (estimate)

Grand Total 160

*Guarani flight demonstration data not available

COUNTRIES REPRESENTED	NO.	FLIGHT DEMO *	
Argentina	200		
U.S.	7		
Australia (IATA)	1		
Canada	3	3	**
Chile	5	4	Air Attache (1)

COUNTRIES REPRESENTED (continued)	NO.	FLIGHT DEMO *	
Uraguay	11	7	Air Attache (1)
Columbia	1		
Venezuela	2	2	
Brazil	3	3	Air Attache (1)
Boliva	2	2	Air Attache
Peru	1	1	Air Attache
Mexico	2	2	Air Attache (1)
Federal Republic of Germany	3	1	
United Kingdom	3	2	
Peoples Republic of China	2		Air Attache
South Africa	1	1	Air Attache
Italy	1	1	Air Attache
Israel	1	1	Air Attache
India	1		
Total	250		

TABLE III

UNITED STATES OF AMERICA
TRSB DEMONSTRATION PROGRAM
BUENOS AIRES, ARGENTINA

OCTOBER 31 THROUGH NOVEMBER 4, 1977

SCHEDULE OF EVENTS

OCTOBER 31	0900 - 1730	Briefing and demonstration for Argentine Aviation Officials
NOVEMBER 1	1000 - 1230	Press briefing tour of ground systems - TRSB Flight Demonstration
	1530 - 1730	Briefing and demonstration for Argentine Aviation Officials - Aeroparque
NOVEMBER 2	0900 - 1300	Briefing and demonstration for Argentine Aviation Officials - Aeroparque
	1045 - 1230	TRSB presentation OAS C.I.T.E.L. meeting
	1430 - 1730	Tour of TRSB ground systems (C.I.T.E.L.) TRSB Flight Demonstration (C.I.T.E.L.)
NOVEMBER 3	0930 - 1730	TRSB Presentation Tour of TRSB Ground Systems TRSB Flight Demonstation
NOVEMBER 4	0930 - 1730	TRSB Presentation Tour of TRSB Ground Systems TRSB Flight Demonstration

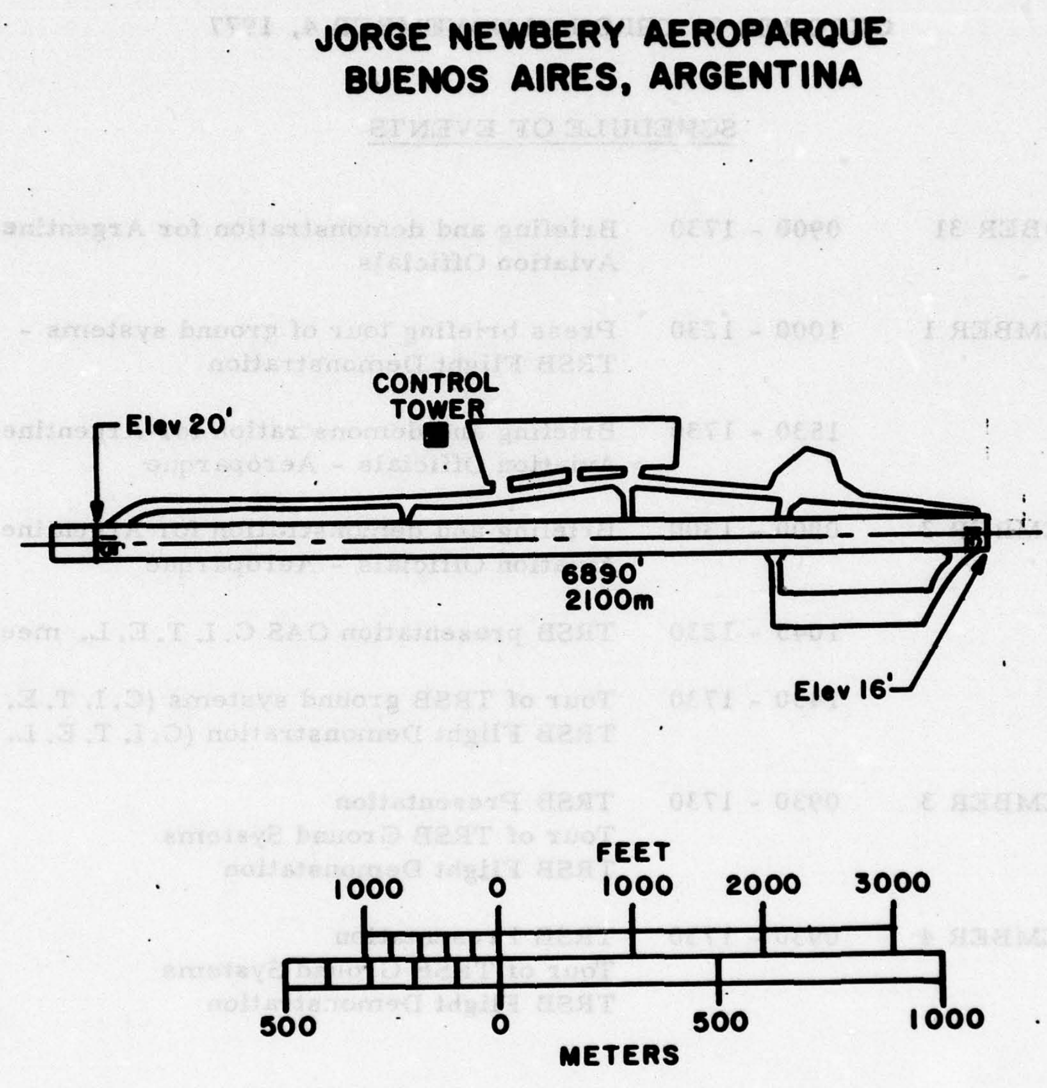


FIGURE 1. AIRPORT LAYOUT

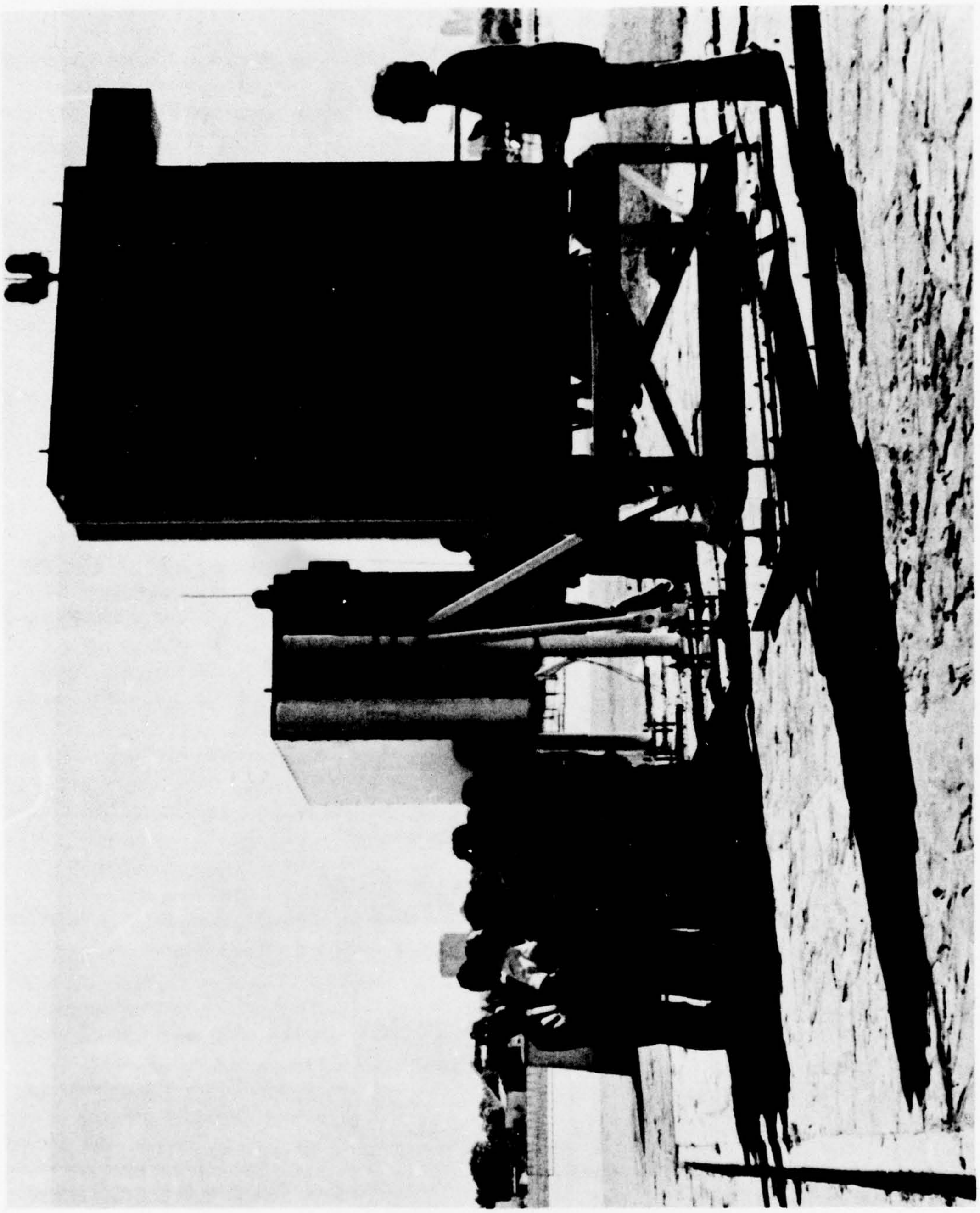


FIGURE 2. TRSB MLS SMALL COMMUNITY SYSTEM DISPLAYED

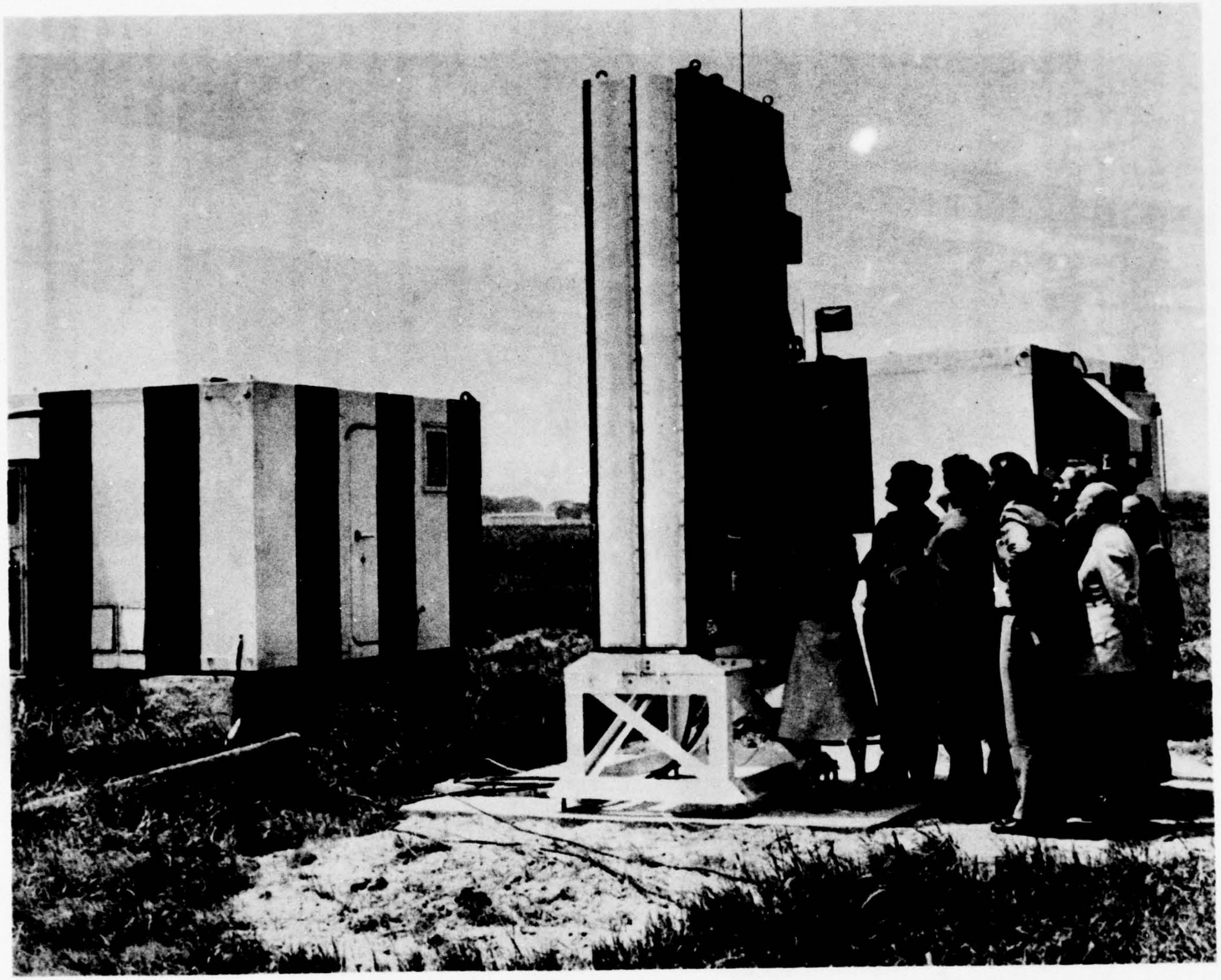


FIGURE 3. BENDIX BASIC NARROW ELEVATION INSTALLATION

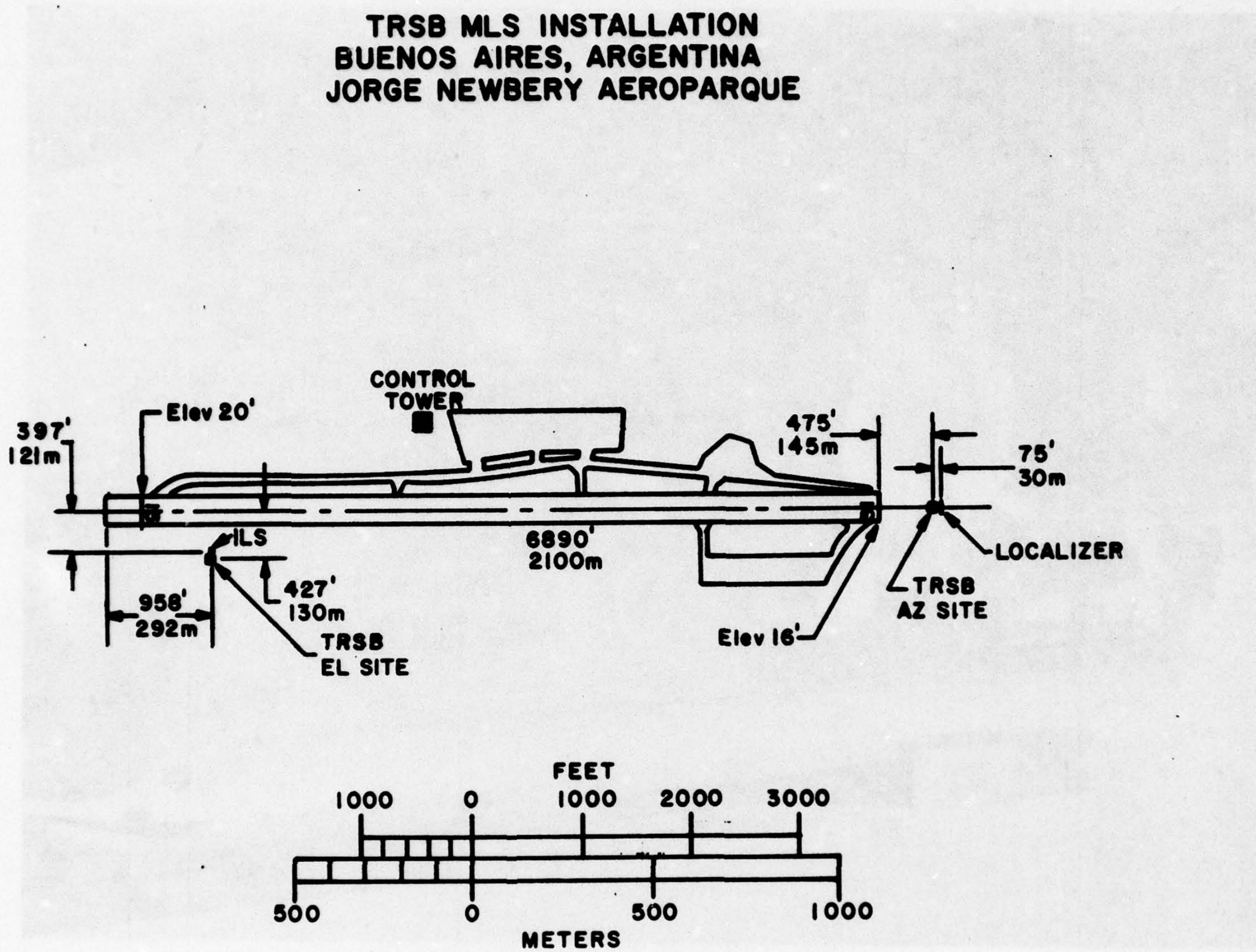


FIGURE 4. TRSB SITING DIAGRAM ON RUNWAY WITH ILS

FIGURE 5.   DEMONSTRATION VAN

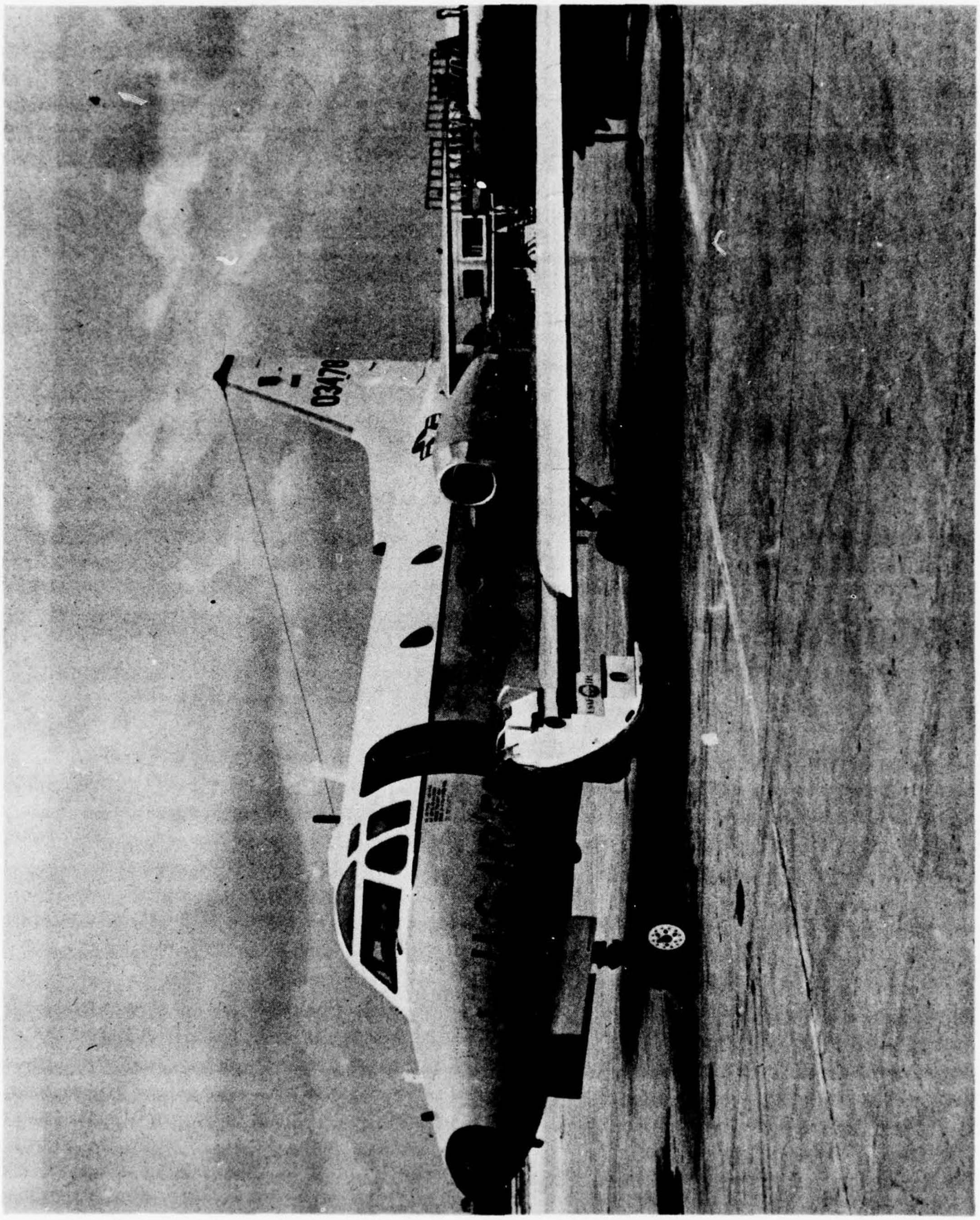


FIGURE 6. T-39 USAF JET

FIGURE 7. NASA B-737

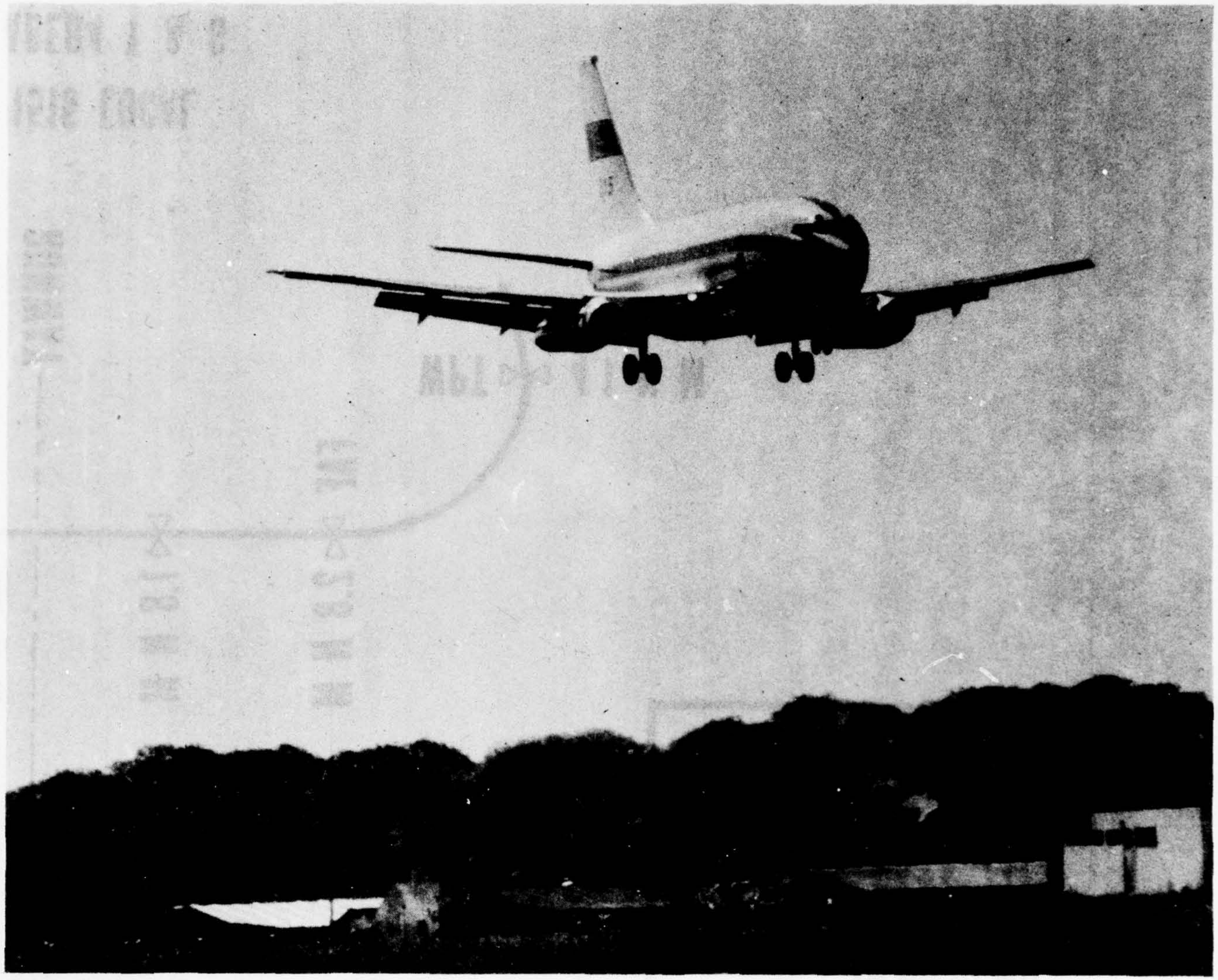


FIGURE 8. NASA B-737 ON 3° APPROACH

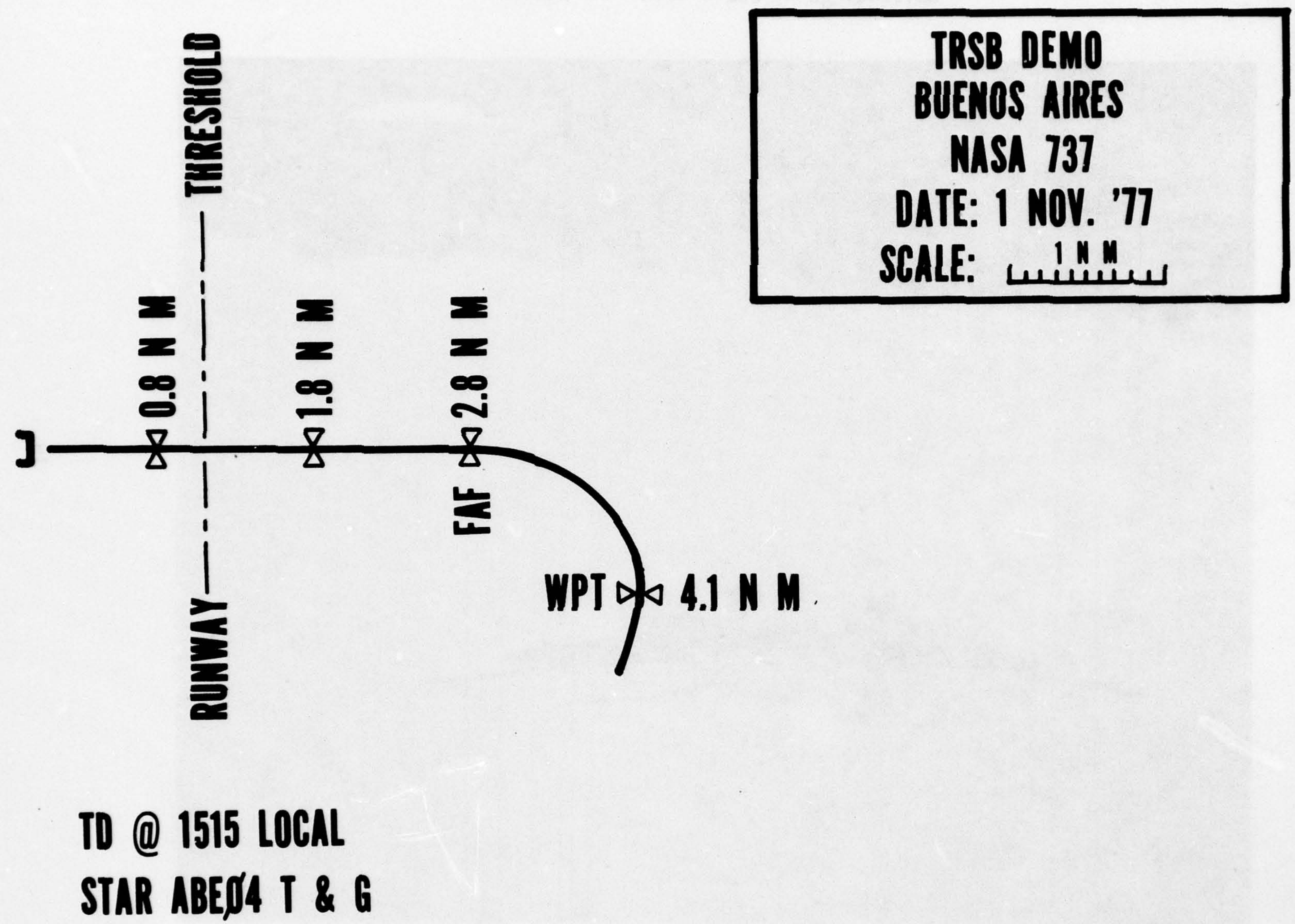


FIGURE 9. NASA B-737 CURVED APPROACH

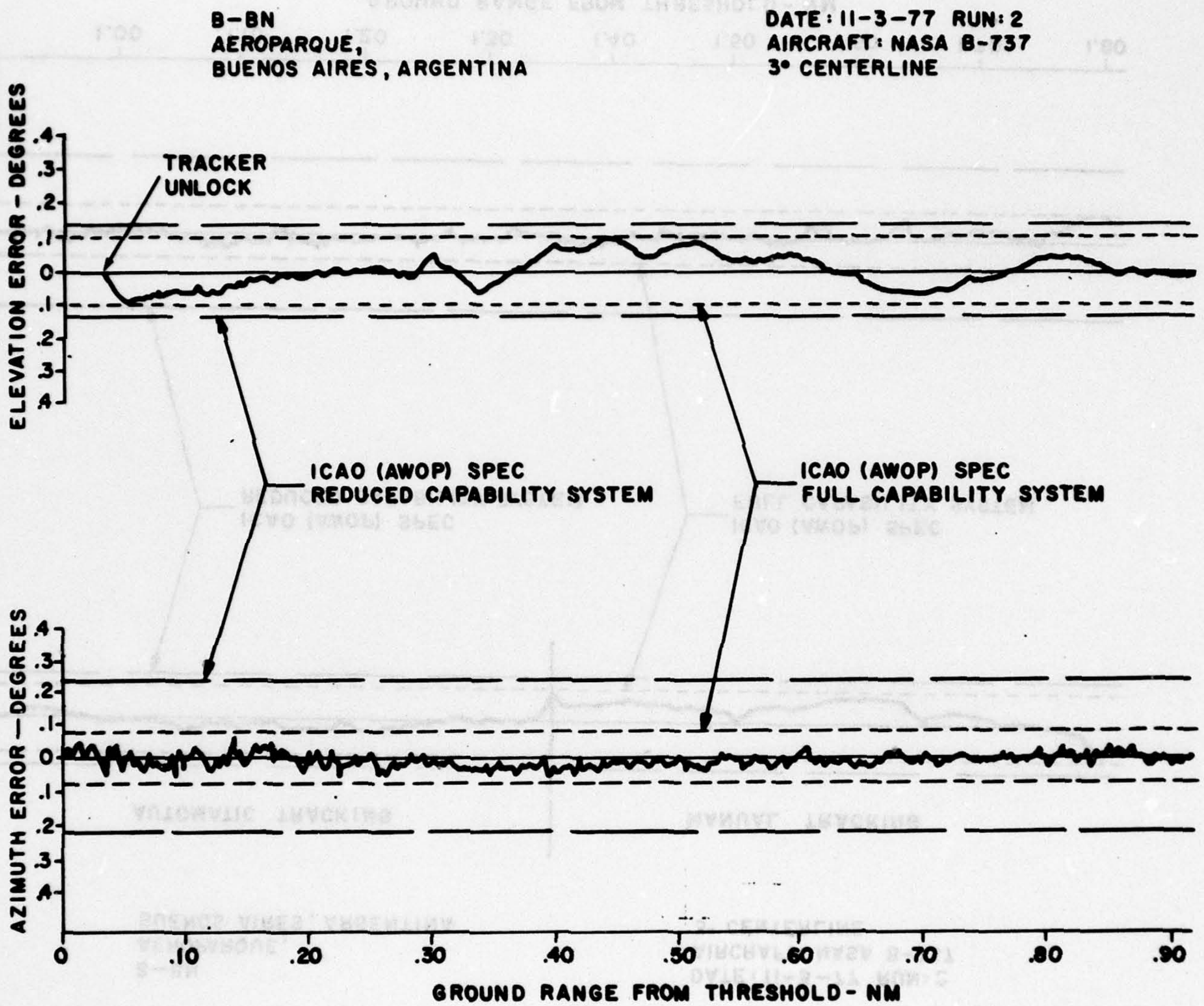


FIGURE 10A. SAMPLE DATA PLOT

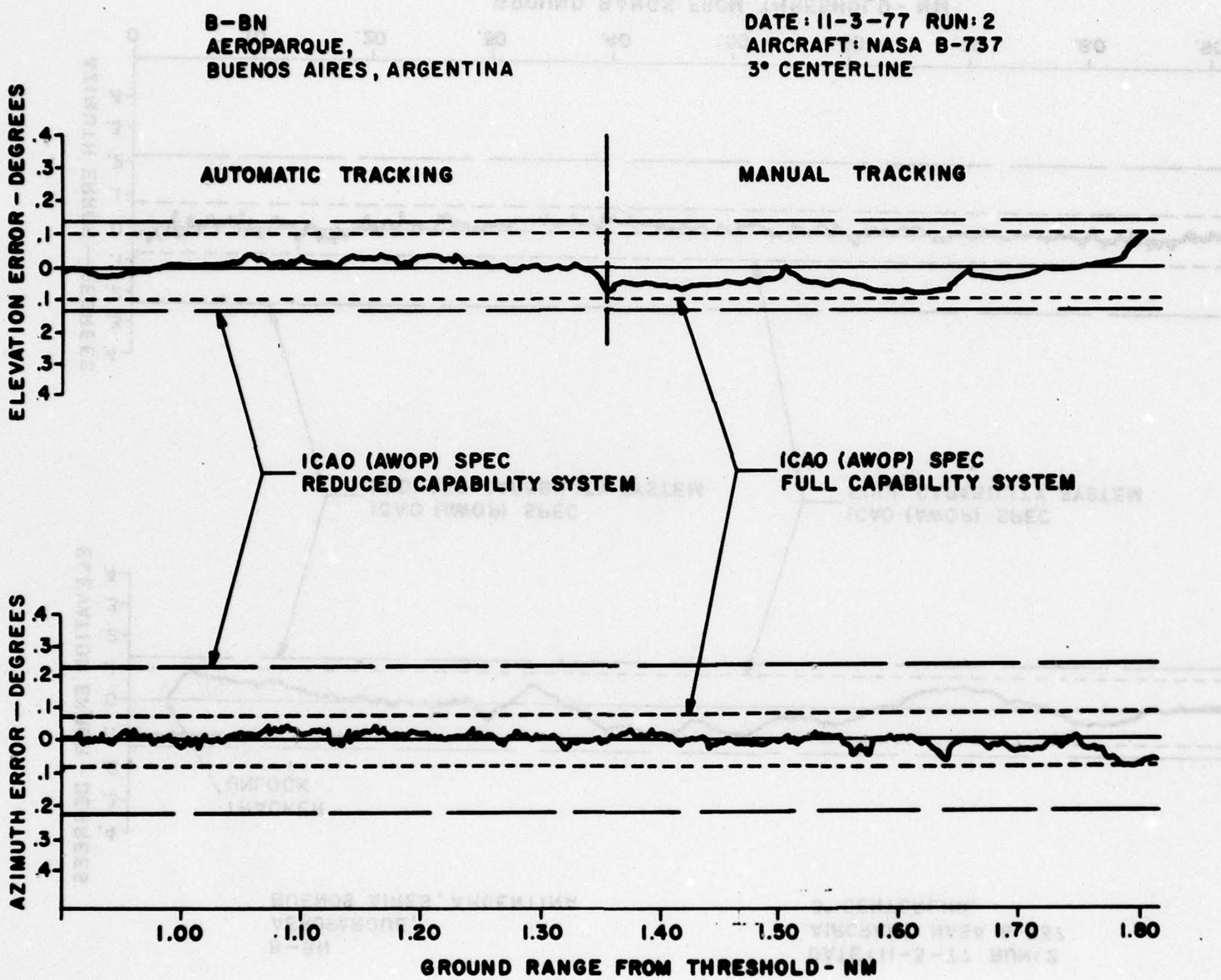


FIGURE 10B. SAMPLE DATA PLOT

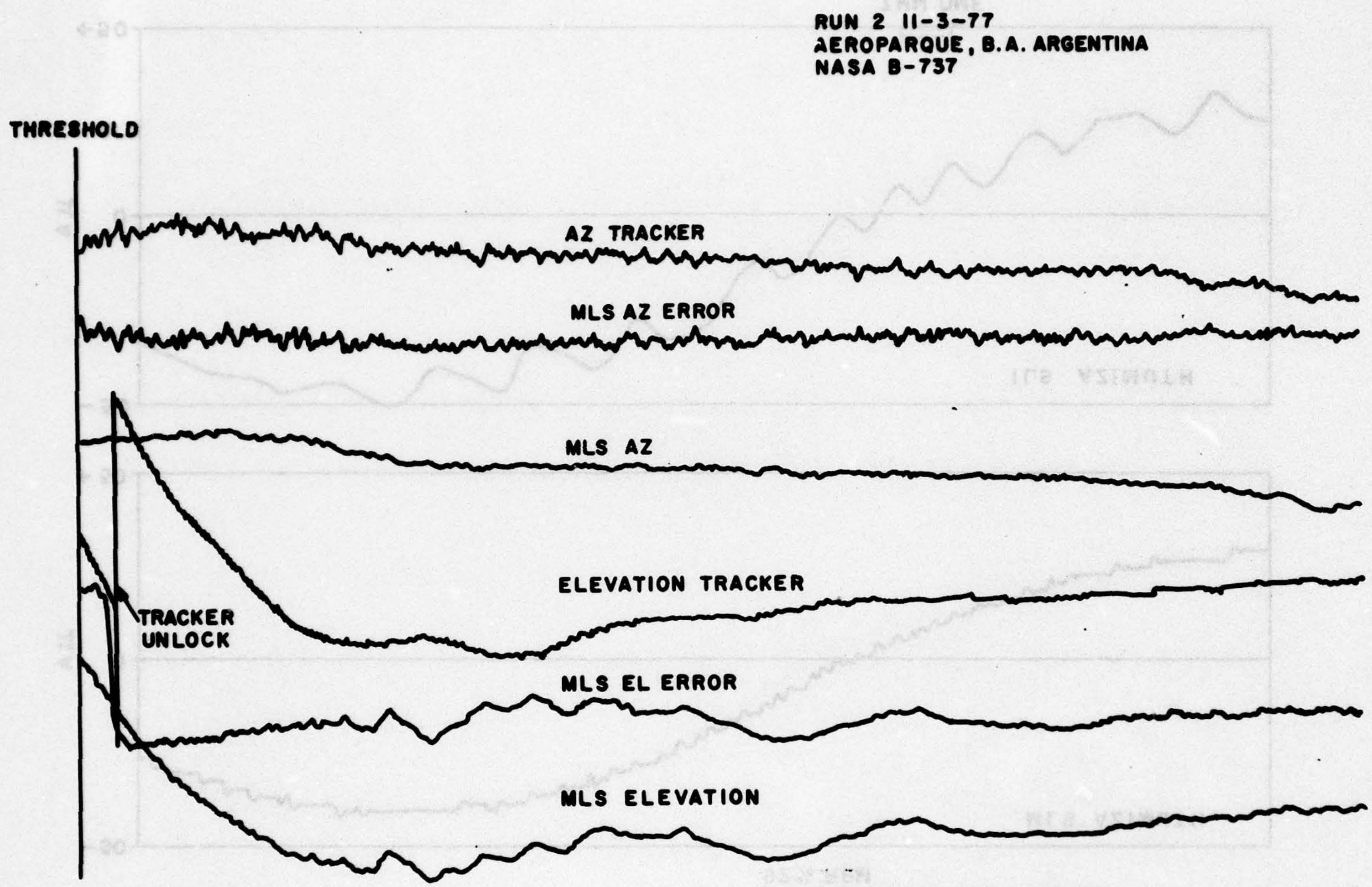


FIGURE 11. STRIP CHART SAMPLE

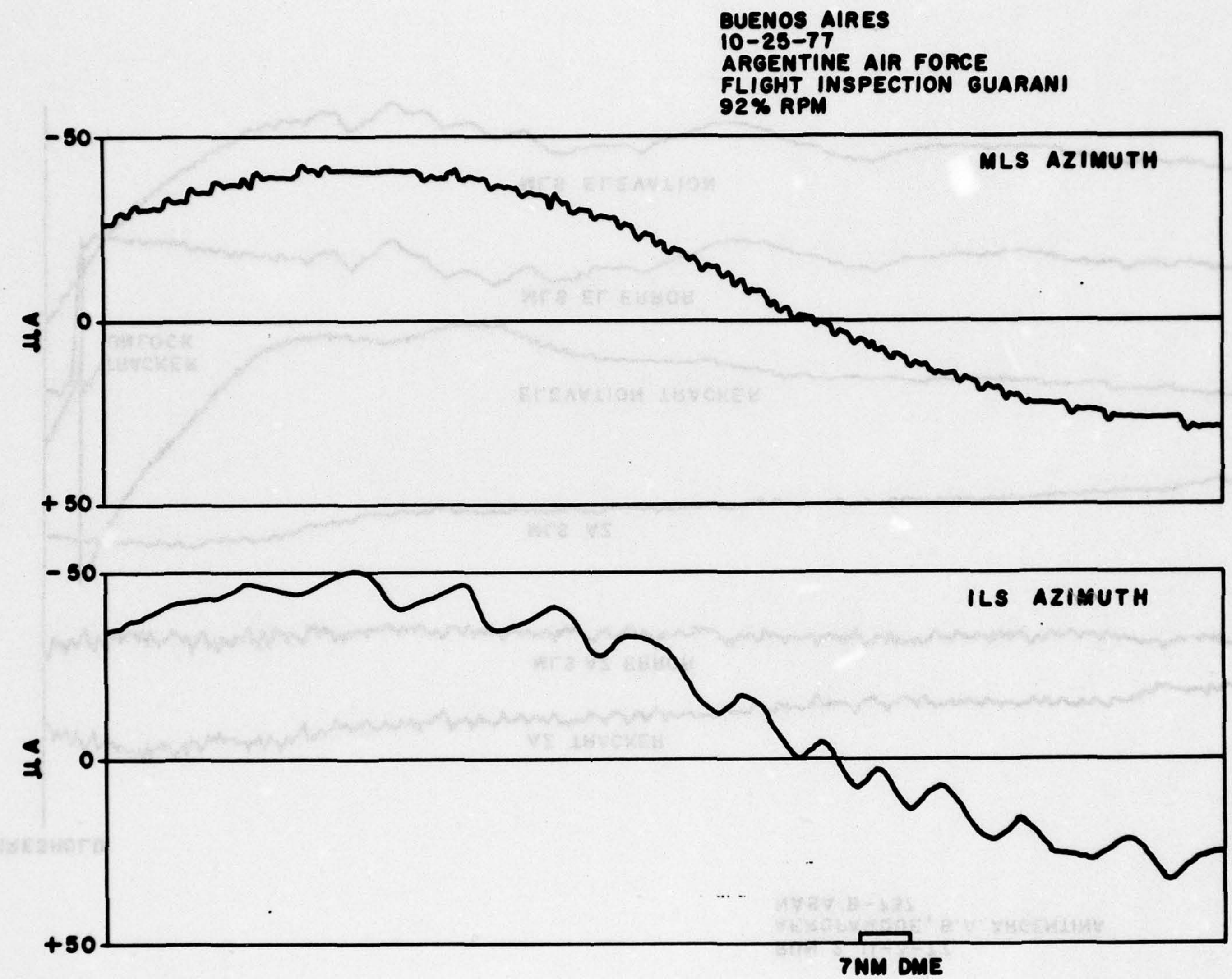


FIGURE 12. GUARANI PROP MODULATION ILS LOCALIZER AND TRSB AZIMUTH

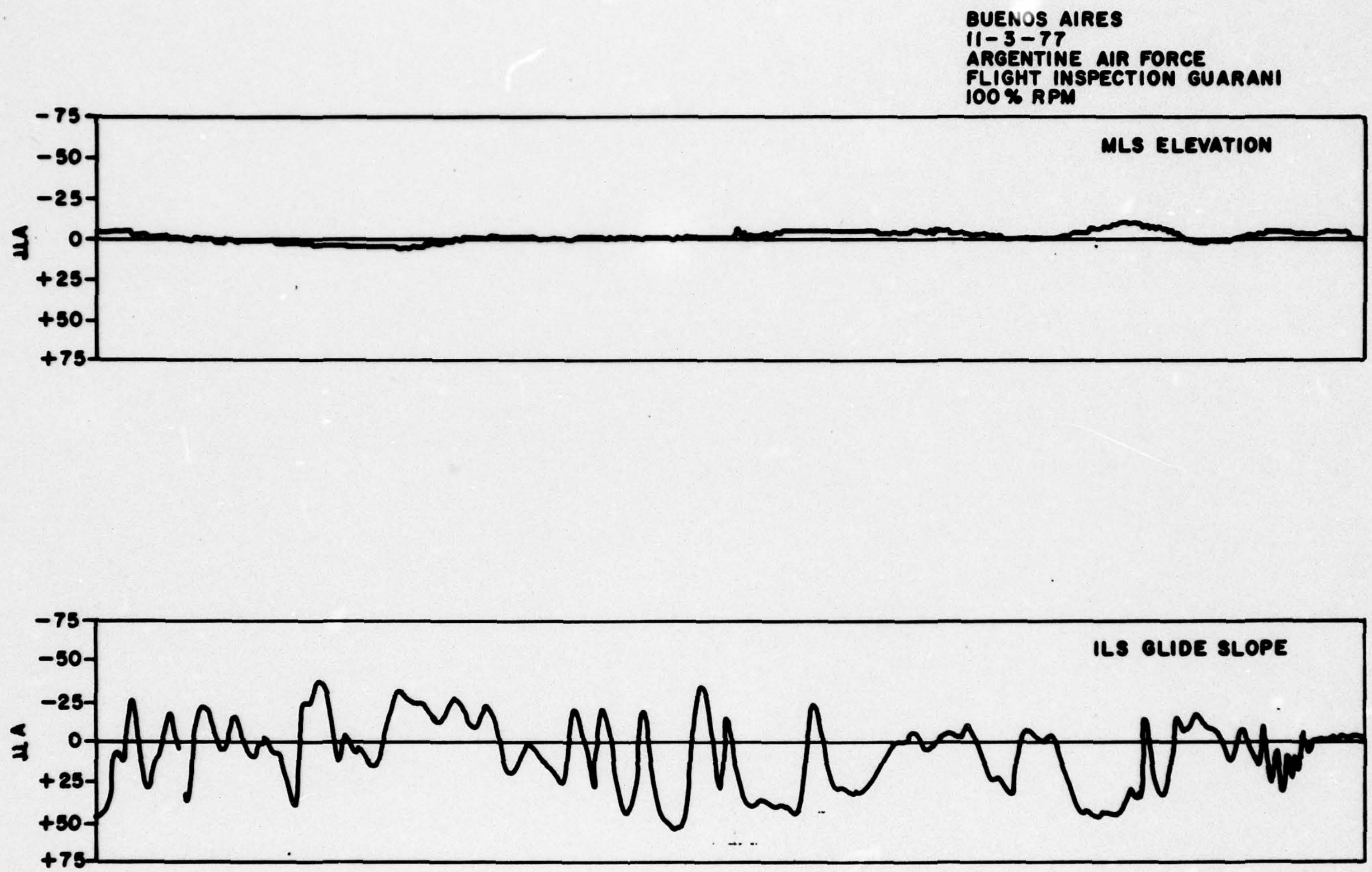
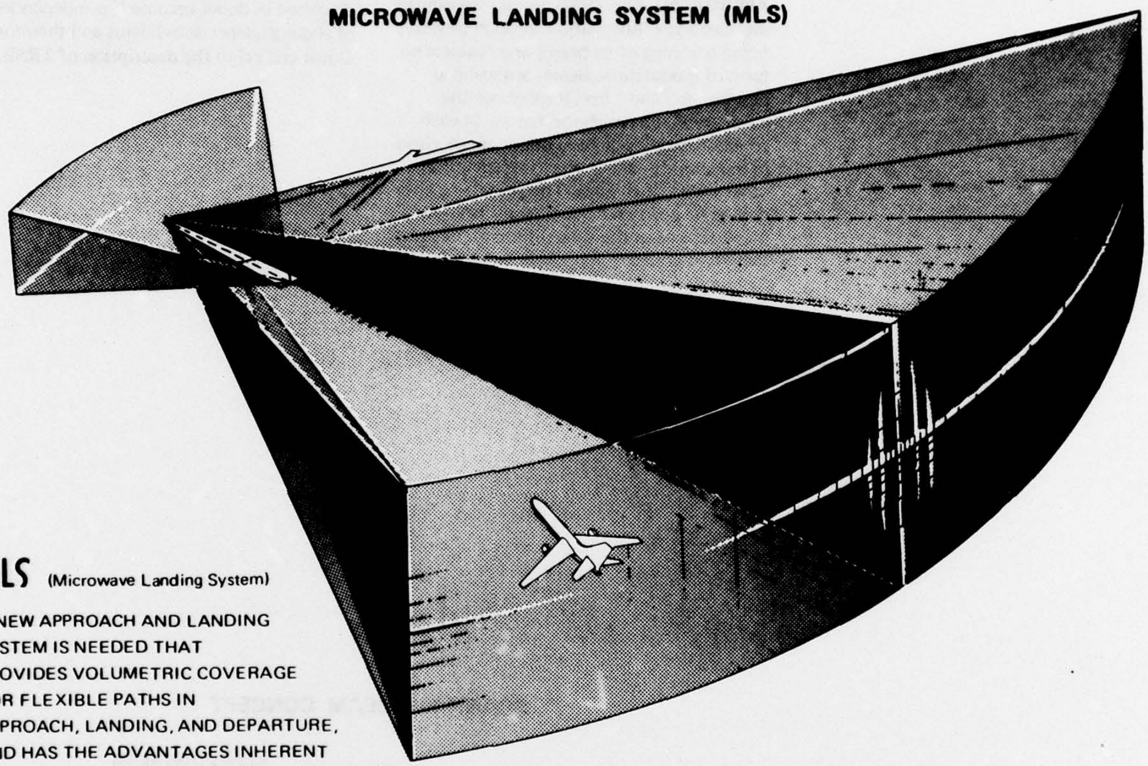


FIGURE 13. GUARANI PROP MODULATION ILS GLIDE SLOPE AND TRSB

APPENDIX A

MICROWAVE LANDING SYSTEM (MLS)



MLS (Microwave Landing System)

A NEW APPROACH AND LANDING SYSTEM IS NEEDED THAT PROVIDES VOLUMETRIC COVERAGE FOR FLEXIBLE PATHS IN APPROACH, LANDING, AND DEPARTURE, AND HAS THE ADVANTAGES INHERENT WITH OPERATING AT MICROWAVE FREQUENCIES

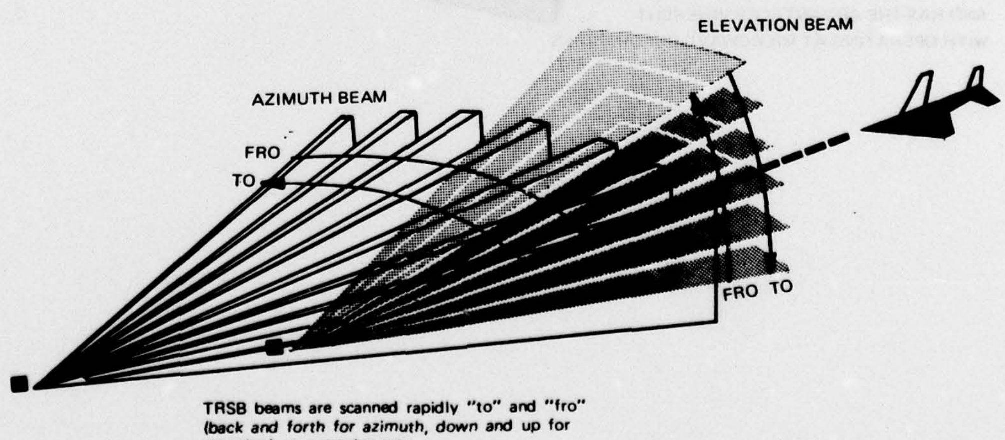
TIME REFERENCE SCANNING BEAM (TRSB) MLS IS AN AIR-DERIVED APPROACH AND LANDING SYSTEM. An aircraft can determine its position in space by making two angle measurements and a range measurement. A simple ground-to-air data capability provides airport and runway identification and other operational data (such as wind speed and direction, site data, and system status).

FAN BEAMS PROVIDE ALL ANGLE GUIDANCE (APPROACH AZIMUTH, ELEVATION, FLARE, AND MISSED APPROACH). The TRSB ground transmitter supplies angle information through precisely timed scanning of its beams and requires no form of modulation. Beams are scanned rapidly "to" and "fro" throughout the coverage volume as shown below. In each complete scan cycle, two pulses are received in the aircraft—one in the "to" scan, the other in the "fro" scan. The aircraft receiver derives its position angle directly from the measurement of the time difference between these two pulses.

RANGE IS COMPUTED IN THE CONVENTIONAL MANNER. TRSB proposes to use L-Band Distance Measuring Equipment (DME) that is compatible with existing navigation equipment. It provides improved accuracy and channelization capabilities. The required 200 channels can be made available by assignment or sharing of existing channels, using additional pulse multiplexing. The ground transponder is typically collocated with the approach azimuth subsystem.

NOTE: The DME (ranging) function is not discussed in detail because it is independent of angle guidance subsystems and therefore **is not critical to the description of TRSB.**

SCANNING BEAM CONCEPT



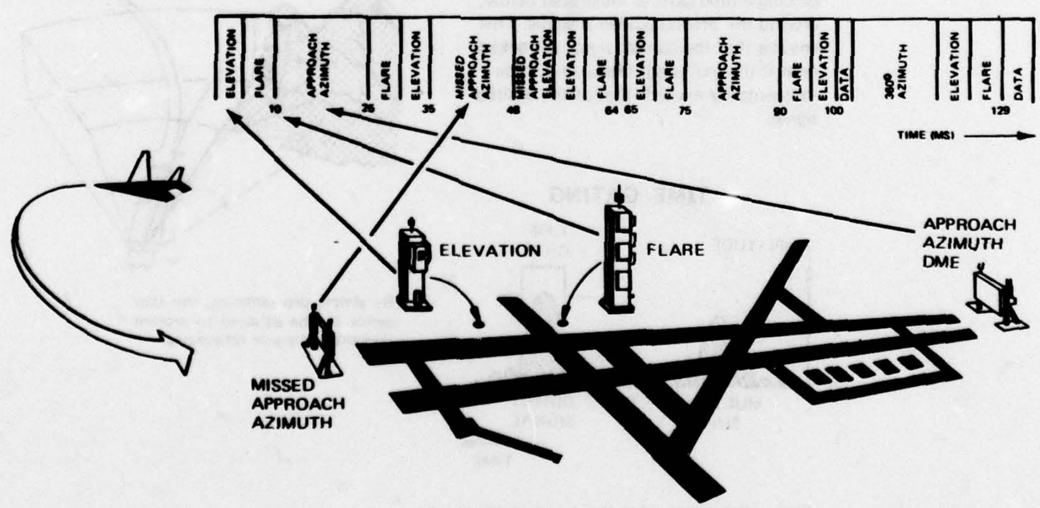
TRSB beams are scanned rapidly "to" and "fro" (back and forth for azimuth, down and up for elevation) at a precise rate

TRSB USES A TIME-SEQUENCED SIGNAL FORMAT FOR ANGLE AND DATA FUNCTIONS. Angle and data functions (that is, approach azimuth, elevation, flare, missed-approach guidance, and auxiliary data) are sequentially transmitted by the ground station on the same channel. Primary operation is C-band, with 300 KHz spacing between channels. However the format is compatible with Ku-Band requirements. (Note: DME is an independent function on a separate frequency and is not a part of this format.)

THE SIGNAL FORMAT IS DESIGNED TO ALLOW A MAXIMUM DEGREE OF FLEXIBILITY. Functions can be transmitted in any order or combination to meet the unique operational needs of each site. This flexibility is made possible by a function preamble identification message. This message sets the airborne receiver to measure the angle or decode the data function that will follow. The ordering or timing of transmissions, therefore, is not important. This flexibility permits individual functions to be added or deleted to meet specific airport requirements. It also permits any TRSB airborne receiver to operate with any ground system. The only requirements are that a minimum data rate (minimum number of to-fro time-difference measurements per second) be maintained for each angle function, and that these measurements be relatively evenly distributed in time. An example of two 64-millisecond sequences of a configuration that utilizes all available functions is illustrated below.

THE TRSB FORMAT PROVIDES FOR CURRENT AND ANTICIPATED FUTURE REQUIREMENTS. Included are

- Proportional azimuth angle guidance to ±60° relative to runway centerline at a 13.5-Hz update rate (that is, data are renewed 13.5 times each second.)
- Proportional missed-approach azimuth guidance to ±40° relative to runway centerline at a 6.75-Hz update rate
- Proportional elevation guidance up to 30° with a 40.5-Hz update rate
- Flare guidance up to 15° with a 40.5-Hz update rate
- 360° azimuth guidance with a 6.75-Hz update rate
- Missed-approach or departure elevation function with a 6.75-Hz update rate
- Basic data prior to each angle function (includes function identification, airport identification, azimuth scale factors, and nominal and/or minimum selectable glide slope)
- Auxiliary data (for example, environmental and airport conditions)
- Facility status data
- Ground test signals
- Available time for other data and/or additional future functions.

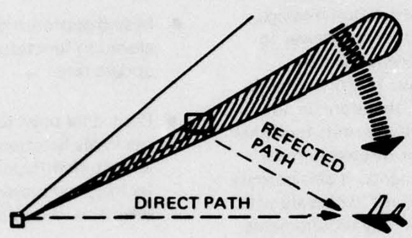


The TRSB signal offers maximum flexibility to meet unique user requirements

TRSB OPERATES EFFECTIVELY IN SEVERE MULTIPATH ENVIRONMENTS. TRSB offers several unique solutions to the multipath problem that has limited the implementation of other landing systems.

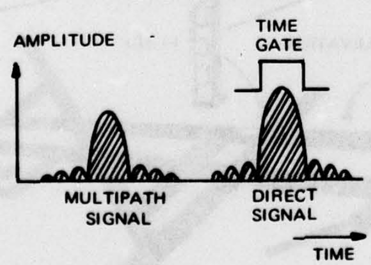
THERE ARE TWO TYPES OF MULTIPATH. Multipath occurs when a microwave signal is reflected from a surface, such as an airport structure, a vehicle, and certain types of terrain. The resulting reflected beam is classified as either out-of-beam multipath or in-beam multipath, depending on its time of arrival in the aircraft receiver relative to the direct signal.

REFLECTED SIGNALS



OUT-OF-BEAM MULTIPATH. If the angle and therefore the time between the reflected and direct beam are relatively large, the aircraft receiver is subjected to out-of-beam multipath. In this case, the TRSB processor automatically rejects the reflected signal by placing a time gate, as illustrated below, around the desired guidance signal. This ensures that the correct signal is tracked even if the multipath signal amplitude momentarily exceeds that of the desired signal.

TIME GATING



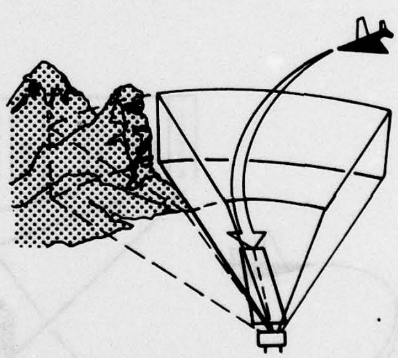
Time gating ensures that the correct signal is tracked, not the reflected one

IN-BEAM MULTIPATH. When the reflected and direct signals reach the aircraft almost simultaneously (the angle of arrival is very small), multipath is said to be in-beam. TRSB combats in-beam multipath by

- Shaping the horizontal pattern of the elevation antenna to reject lateral reflections
- Motion averaging, by utilizing the high data rates of TRSB
- Processing only the leading edge of the flare/elevation beam, which is not contaminated by the ground reflections.

COVERAGE CONTROL IS AVAILABLE TO ELIMINATE MULTIPATH AT EXTREMELY SEVERE PROBLEM SITES. Any MLS system will experience acquisition or tracking problems in those cases where the reflected signal is known to be persistent and greater in amplitude than the direct signal. A TRSB feature called coverage control can be implemented, at no cost, in such cases by simply programming the Beam Steering Unit (BSU). This feature permits a simple adjustment of the ground facility to limit the scan sector in the direction of the obstacle and thereby prevents acquisition of erroneous signals.

SELECTIVE COVERAGE CONTROL



By simple programming, the scan sector can be adjusted to prevent undesired obstacle reflections

TRSB IS A MODULAR SYSTEM WHICH CAN BE CONFIGURED TO MATCH THE NEEDS OF THE USER. A set of phased-array subsystems has been designed that may be installed in any combination to meet the broad range of user requirements.

The minimum system configuration consists of approach azimuth and elevation subsystems. Flare, missed-approach, and range subsystems may be included or added later. Several antenna beamwidths are available, as indicated in the table below, from which a ground configuration can be designed to provide guidance signals-in-space of uniform quality in all airport environments.

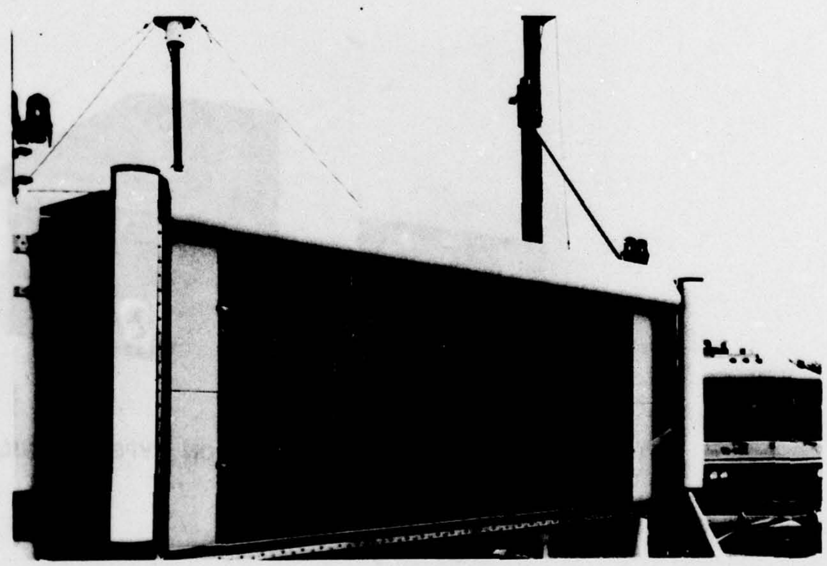
NOTE: DME is an independent subsystem which is combined with appropriate azimuth and elevation subsystems to make up the total guidance system.

GROUND ANGLE SUBSYSTEMS

SUB-SYSTEM	NOMINAL BEAMWIDTH (DEGREES)	COVERAGE (DEGREES) *	PRINCIPAL APPLICATIONS
Azimuth	1	Up to ± 60	Approach Azimuth; Long Runways
Azimuth	2	Up to ± 60	Approach Azimuth; Intermediate Length Runways
Azimuth	3	Up to ± 60	Approach Azimuth; Short Runways Missed Approach Azimuth
Elevation	0.5	Up to 15	Flare
Elevation	1	Up to 30	Elevation (Severe multipath sites)**
Elevation	2	Up to 30	Elevation (Less severe multipath sites)**

* Coverage determined by Beam Steering Unit (BSU) for all arrays.

** **See multipath discussion.**



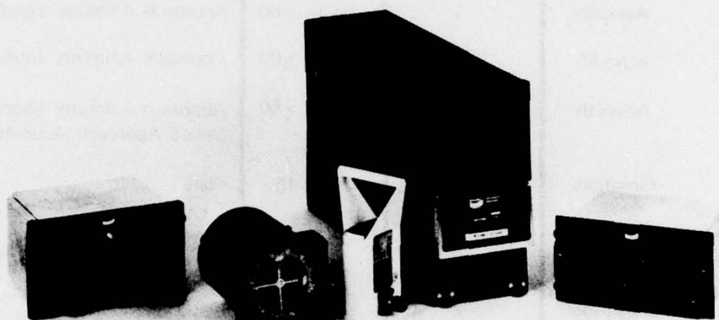
Phased Array Azimuth Antenna installed at the National Aviation Facilities Experimental Center. Radome is rolled back to expose radiating elements.

AIRBORNE RECEIVER DESIGNS ALSO STRESS THE MODULARITY CONCEPT. Users need only procure what is necessary for the services desired from any ground facility. To obtain approach and landing guidance at the lowest cost, an aircraft needs only an antenna and a basic receiver-processor unit operating with existing ILS displays. An air-transport category aircraft equipped for operation to low-weather minimums will carry redundant equipment and, in the future, advanced displays to fully utilize all of the inherent operational capabilities provided by TRSB.

The 200-channel TRSB angle receiver-processor provides angle information from the scanning beam azimuth and elevation subsystems and decodes the auxiliary data for display. Special monitoring ensures the integrity of the receiver output.

A second airborne unit is the DME. It is channeled to operate with the angle receiver-processor and provides a continual readout of distance.

Both the angle receiver-processor and the DME provide standard outputs to existing flight instruments and autopilot systems. An optional airborne computer would be used to generate curved or segmented approaches based on TRSB position information.



AIRLINE TYPE AVIONICS

GENERAL AVIATION TYPE AVIONICS

TRSB CAN PROVIDE ALL-WEATHER LANDING CAPABILITY AT MANY RUNWAYS THAT PRESENTLY DO NOT OFFER THIS SERVICE. This is made possible by

- The proposed channel plan, which contains enough channels for any foreseeable implementation
- High system integrity and precision
- Minimum siting requirements.

THE LARGE COVERAGE VOLUME PROVIDES FLIGHT PATH FLEXIBILITY. Transition from en route navigation is enhanced through the wide proportional coverage of MLS. Such flexibility in approach paths, coupled with high-quality guidance, can be used to achieve

- Improvements in runway and airport arrival capacity
- Better control of noise exposure near airports
- Optimized approach paths for future V/STOL aircraft
- Intercept of glide path and of runway centerline extended without overshoot
- Lower minimums at certain existing airports by providing precise missed-approach guidance
- Wake vortex avoidance flight paths.

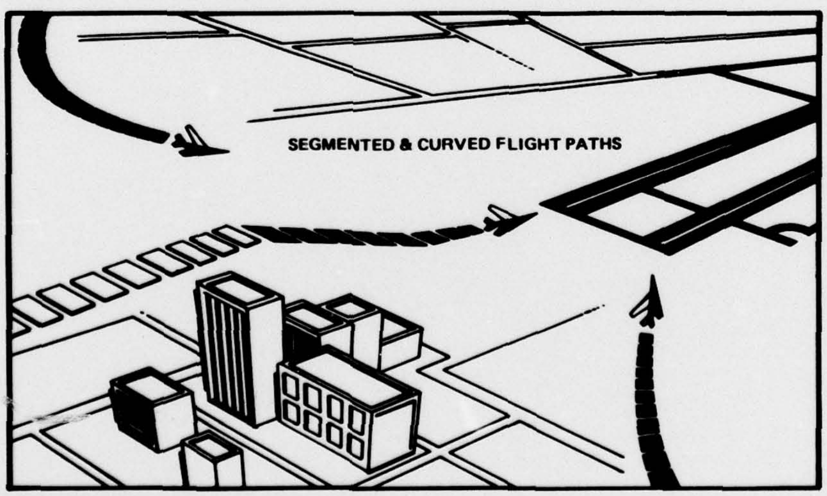
THE TRSB SIGNAL FORMAT ENSURES THAT EVERY AIRBORNE USER MAY RECEIVE LANDING GUIDANCE FROM EVERY GROUND INSTALLATION. Compatibility is ensured between facilities serving international civil aviation and those serving unique national requirements.

TRSB SPANS THE ENTIRE RANGE OF APPROACH AND LANDING OPERATIONS FOR ALL AIRCRAFT TYPES. This includes CTOL, STOL, and VTOL aircraft operating over a wide range of flight profiles. The particular needs of users, ranging from general aviation to major air carriers, are accommodated. TRSB is adaptable to special military applications, such as transportable or shipboard configurations on a compatible basis with civil systems.

HIGH RELIABILITY, INTEGRITY, AND SAFETY OF TRSB ARE ENHANCED BY SEVERAL IMPORTANT FEATURES. These include

- Simple TRSB receiver processing
- Multipath immunity features on the ground and in the airborne receiver-processor
- A comprehensive monitoring system that verifies the status of all subsystems and the radiated signal. Status data are transmitted to all aircraft six times each second.
- Coding features, such as parity and symmetry checks, that prevent the mixing of functions.

TRSB PROVIDES CATEGORY-III QUALITY GUIDANCE. TRSB signal guidance quality has already been proved via demonstration of fully automatic landings, including rollout, in a current commercial transport aircraft (Boeing 737) and an executive jet (North American Sabreliner).



TRSB provides precision guidance for curved and segmented approaches for noise abatement and traffic separation, as well as for autoland and rollout